2021

The Effect of an Acidified-Gypsum Mixture on Broiler Litter Urease-Producing Bacteria and Nitrogen Mineralization

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Introduction

- The United States poultry industry produced more than 9 billion broiler chickens (*Gallus gallus domesticus*) in 2018, making it one of the largest meat producers in the world[1].
- Georgia has led the nation in broiler production for decades. Three out of four Georgia counties are involved in the industry producing about $6 billion each year.
- The floor of a broiler house is covered with broiler litter: a mixture of bedding material, excreta, spilled feed, and feathers.
- Broiler litter is rich in organic nitrogen (N) with the most common forms being uric acid and urea [2,3].
- The break down of urea is a microbially-mediated process in which ammoniacal-N (NH_3/NH_4^+) and carbon dioxide (CO_2) are produced.
- Ammonia (NH_3) volatilization from broiler litter can decrease bird productivity and serves as an environmental pollutant.
- Litter pH is the most prominent litter characteristic affecting NH_3 volatilization.
- Acidifying amendments, such as aluminum sulfate (alum), have emerged as the most common litter amendments because: (i) they decrease urease-producing bacteria (PLUPs) that breakdown urea[5,6,9,10] and (ii) favor NH_4^+ formation rather than NH_3 volatilization.
- Gypsum has been suggested as an amendment to reduce NH_3 volatilization from broiler litter, but results vary among studies [8,11,12,13,14,15,16,17].
- There is limited research that directly compares the effect of alum and gypsum on NH_3 volatilization [8,13,14].

Figure 1: An example of a broiler chicken house in Georgia[18].

Objectives

- The objective of this research was to create a gypsum-alum mixture that has a pronounced effect on litter pH, PLUP abundance, NH_3 volatilization, inorganic-N and $CaCO_3$ precipitation during a 33-d incubation.
- We hypothesized that amending broiler litter with a gypsum-alum mixture would have a greater effect on NH_3 volatilization than gypsum alone due to a more significant decrease in litter pH on day 0.
- This decrease in pH should limit cumulative NH_3 loss from litter by favoring NH_4^+ formation and decreasing PLUP abundance.
- We also predicted that the dissolution of gypsum in the FGDG-alum amended litter would decrease PLUP concentrations more than acidifying alone due to osmotic stress and extracellular $CaCO_3$ formation.

Materials and Methods

- Broiler litter was collected from a broiler house in Georgia, USA, (Figure 1). Litter was analyzed for pH, water content, total C and N, and inorganic N (NH_4^+-N and NO_3^--N).
- Treatments included: 1) broiler litter only (BL), 2) broiler litter + FGDG (BL + FGDG), 3) broiler litter + FGDG + 6% alum (BL + FGDG + A6), 4) broiler litter + 6% alum (BL+A6), and 7) broiler litter + 10% alum (BL+A10).
- Flue-gas desulfurization gypsum (FGDG) was used as our source of gypsum.

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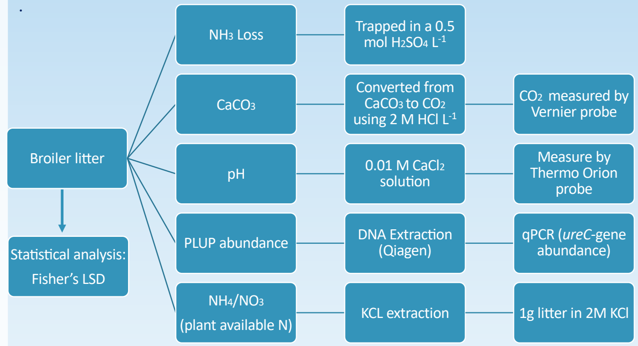

Results

Table 1: Litter pH and *ureC* gene copies in broiler litter (BL), broiler litter + FGDG (BL+FGDG), broiler litter + FGDG + 6% alum (BL+FGDG+A6), broiler litter + 6% alum (BL+A6), and broiler litter + 10% alum (BL+A10) during a 33-d incubation at 23ºC

Treatment	Day 0		Day 19		Day 33	
	pH	ureC gene copies ($x10^5$)	pH	ureC gene copies ($x10^5$)	pH	ureC gene copies ($x10^5$)
BL	6.64 (0.02)^a	80.1 (36.8)^a	7.83 (0.04)^a	7760 (1880)^a	8.42 (0.07)^a	481 (227)^a
BL+FGDG	6.55 (0.01)^b	5.45 (1.20)^b	7.77 (0.03)^a	147 (45)^b	8.35 (0.03)^a	13.5 (6.67)^c
BL+FGDG +A6	6.22 (0.03)^c	BD^2	7.32 (0.08)^b	25 (9.68)^b	7.74 (0.06)^b	2.84 (0.658)^c
BL+A6	5.97 (0.09)^d	BD^2	7.09 (0.12)^c	50.4 (21.5)^b	7.58 (0.01)^c	302 (43.6)^a
BL+A10	5.45 (0.09)^e	BD^2	6.96 (0.04)^c	36.2 (8.78)^b	7.31 (0.11)^d	81.6 (42.7)^b
p-value	<0.001	0.036	<0.001	<0.001	<0.001	<0.001

Table 2: Cumulative NH_3 loss and inorganic nitrogen concentrations in broiler litter (BL), broiler litter + FGDG (BL+FGDG), broiler litter + FGDG + 6% alum (BL+FGDG+A6), broiler litter + 6% alum (BL+A6), and broiler litter + 10% alum (BL+A10) at end of a 33-d incubation at 23ºC.

Treatment	NH_3-N loss (µg g^{-1})	NH_4-N (µg g^{-1})	NO_3-N (µg g^{-1})	Total N recovered	
				µg g^{-1}	% Total N
BL	5,745 (54.5)^a	3,511 (370)^c	16.8 (3.98)^a	9,273 (404)^b	32.4 (1.41)^b
BL+FGDG	5,915 (128)^a	5,032 (114)^b	6.85 (0.769)^b	10,954 (202)^a	38.3 (0.71)^a
BL+FGDG+A6	4,435 (337)^b	5,613 (99.4)^a	7.65 (0.329)^b	10,055 (349)^{ab}	35.2 (1.22)^{ab}
BL+A6	3,308 (128)^c	4,646 (108)^b	6.45 (0.317)^b	7,960 (209)^c	27.8 (0.73)^c
BL+A10	2,373 (389)^d	5,012 (96.6)^b	5.63 (0.175)^b	7,390 (267)^c	25.8 (0.93)^c
p-value	<0.0001	<0.0001	0.0050	<0.0001	<0.0001

Discussion

- Amending broiler litter with acidified-gypsum had a more pronounced effect on litter pH throughout the study compared to gypsum alone ($p = 0.0001$) (Table 1), and this led to a decrease in cumulative NH_3 loss after 33 d (Table 2).
- Amending broiler litter with 6 and 10% alum generated the greatest effect on litter pH on day 0 ($p < 0.001$) (Table 1), and this effect continued for the rest of the study.
- Flue-gas desulfurization gypsum (FGDG) was the only amendment in this study that did not affect litter pH or NH_3 loss ($p > 0.05$) after 33 d (Table 2). Burt et al., (2018)[17] conducted a similar experiment in which the addition of gypsum decreased litter pH due to the precipitation of $CaCO_3$.
- In the current study, the addition of FGDG did not increase $CaCO_3$ precipitation in litter ($p = 0.47$). We hypothesize that $CaCO_3$ precipitation in litter is strongly influenced by pH, and precipitation will not occur in litter with a pH < 7.75 .
- After 33 d, the lowest concentrations of *ureC* gene copies were detected in broiler litter treated with our gypsum-alum mixture and FGDG alone even though the treatments did not have the lowest pH (Table 1).
- Based on our results, pH is the most prominent factor controlling NH_3 volatilization from broiler litter.
- Amending litter with alum alone was the most effective management practice to control pH and NH_3 volatilization.
- Other sources of gypsum should be explored because FGDG contains $CaCO_3$ which decreased the acidifying effect of our amendment.

Acknowledgements

I would like to thank Dr. Burt, Dr. Bachoon, Dr. Cabrera, and Christopher Horack for all their support and help throughout this project. This research was funded by the 2018 GCSU Faculty Research Grant. This poster presents data from a manuscript that was accepted by the Journal of Environmental Quality.

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